The operationalization of scientific emigration loss 1933-1945: a methodological study on the measurement of a qualitative phenomenon

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A Methodological Study on the Measurement of a Qualitative Phenomenon

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Abstract: In analyzing traditional and current contentions on the »emigration loss« suffered by German science between 1933 and 1945 the validity of quantitative conclusions drawn by several authors is shown to depend crucially on chosing the correct reference group. Some recent contributions not fulfilling this condition tend to grossly overestimate the loss concurring with the process of Nazi seizure of power. An indepth analysis of the emigration losses suffered by the physics community in Germany, however, leads to the conclusion that the usual concept the »emigration loss« itself is logically defect. Three basically different operationalizations of the concept are empirically tested: 1. person oriented definitions; 2. literature (productivity) based definitions; and 3. scientific excellency (citation) based definitions. In addition, more qualitative dimensions of emigration loss are identified: a. loss in core specialties vs. loss in peripheral specialties, b. loss in scientific leadership vs. loss in »indians«. It is proved that the loss experienced by German physics upsurges with shifting from operationalization 1 to 2 or 3, and from 2 to 3, and that the loss in scientific leadership in core specialties of physical science was extremly high. In the case of nuclear physics the loss in scientific excellence thus definined is calculated as amounting to about 50%.

It is almost generally accepted that the rise of Nazism and the implementation of Nazi policies within the German secondary educational sy-

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stem proved detrimental to the further development of many scientific fields within German science and to its international recognition. As one of the *major factors* contributing to this effect historians of science have identified the dismissal of Jewish and politically »unreliable« scientists in the wake of Nazi seizure of power in Germany, »connection« of Austria, and invasion of Czechoslovakia.

Nonetheless, no clear consensus has yet emerged about exactly how much science in Germany was impaired by racial or political dismissals, and by the subsequent emigration of the scientists involved. Apart from the difficult problem of comparatively evaluating scientific development in Germany and its major competitors, not even purely quantitative relations are firmly established. Without even attempting to document in detail the history of statistical estimations trying to uncover the proportion of dismissed scientists, and the occasionally confused making use of these estimations in studies of scientific emigration, we shall confine to briefly examine two of the more founded, albeit statistically not invulnerable attempts at contructing an appropriate measure of the German scientific »emigration loss«. After this short review of the **»State** of the art« we proceed with a critique of some current usage of earlier estimations, and with an attempt to arrive at a better solution.

One of the earliest, and surely one of the best, investigations of Nazi science policy and its effects on the staffs of the German higher academic institutions is due to the American sociologist Edward Y. Hartshorne (1), who had been visiting Germany in 1935/36. Analyzing university calendars and other readily available material Hartshorne was able to draw fairly precise conclusions about changes in research and teaching personnel in the years since the Nazis seized power. Of the academic staff enlisted in Winter Semester 1932/33, making a total of 7.979 persons (exempting the Emeritii and the assistants) for all institutions of higher education, 1.145, or 14.35%, had been dismissed by April 1936 (again exempting the Emeritii and the assistants). Including the assistants would reduce the rate of the dismissed to about 12.8% (1.377 from 10.737).

Historians making use of statistical figures sometimes find it difficult to choose the correct reference groups for comparing different subpopulations. Even one of the most respected researchers in the field, Horst Möller, contributor to volume II of the renowned »International Biographical Dictionary of Central European Emigrés 1933-1945«, edited by Herbert A. Strauss and Werner Röder, is not immune to incorrectly comparing inappropriate categories of dismissed scholars. In his contribution to the XXI. Symposium of the German »Gesellschaft für Wissenschaftsgeschichte«, held in Wolfenbüttel in 1983, Möller writes:

»An den deutschen Universitäten, Technischen Hochschulen und sonstigen wissenschaftlichen Hochschulen gab es im Wintersemester 1930/31

insgesamt 2741 ordentliche Professoren. Daneben gehörten dem Lehrkörper 1741 beamtete oder nichtbeamtete außerordentliche Professoren und 1779 Privatdozenten oder festangestellte Dozenten an. Von diesen insgesamt 6261 an den Universitäten hauptamtlich lehrenden habilitierten Wissenschaftlern waren 517 emeritiert oder pensioniert, so daß 5744 als aktive Universitätslehrer übrigbleiben. Die Professorengruppe insgesamt umfaßte also 4482 Personen. Ich nenne diese Vergleichszahlen, um das Ausmaß der Amtenthebungen durch die nationalsozialistischen Machthaber beziehungsweise der Vertreibung der wissenschaftlichen Elite deutlich zu machen. Wenn die von Gumbel geschätzte Zahl allein für das Deutsche Reich bis 1938 zutrifft, die besagt, daß rund 1500 Professoren entlassen wurden, und wir diese Zahl auf die Professorengruppe insgesamt beziehen, dann bedeutet das: Etwa ein Drittel der hauptamtlichen deutschen Hochschullehrer wurde ihres Amtes enthoben.« (2)

These figures severely distort the true proportions, as presented by Gumbel and Hartshorne. Because Hartshorne's study is not easily available in Germany, I shall reproduce two of the tables from it. On page 95 Hartshorne compares the »Differential losses in the major types of Hochschulen (exclusive of assistants)«:

	Staff in Office W.S. 1932/3	Dismissals up to April 1936	Percent
Universities	5790	953	16.6
Technische Hochschulen	1476	158	10.7
Handelshochschulen	263	28	10.6
Others	450	6	1.3
Total	7979	1145	14.3

In the figures of the first row only scientists in active service are included. »The proportion (of the dismissed) would be smaller if one were to include both Tns' and 'Outs' in reckoning the size of the original staff, a quite unjustifiable inclusion, since only dismissals from active service are being considered, those already retired because of age who lost their pensions being disregarded.« (p. 94) Relying on »Statistisches Jahrbuch für das Deutsche Reich«, Hartshorne (p. 87ff.) gives the total number of faculty staff for 1932/33 as 11.273 (including 2.758 assistants and 8.515 other faculty staff - among them 536 Emeritii). Not included in these figures are employees of Kaiser-Wilhelm-Institute, State foundations, and non-State scientific institutes.

In addition to this, Hartshorne presents the following figures referring to other types of scholars, but now without summary statistics for »Staff in

Office« (p. 93), and therefore (exempting the assistants) without giving us the means to compare them with the ground sample:

Assistants	232
Employees of Non-University Scientific Institutes	133
Recent Graduates	105
Intellectuals	69
Total	539

Adding the sums of both tables results in a total of 1684 dismissed scholars. Of course this figure can no longer be compared with the basic sample of 7.979 staff members, or - even more absurd, but nevertheless often to be seen in the literature - with only the subgroup of full professors. The basis for comparison must now include all the assistants, all employees of non-university scientific institutes, all recent graduates, and all intellectuals. Because figures for the three last subgroups are not given by Hartshorne, we must confine to adding the assistants to both the dismissed group and the basic sample giving 1.377 dismissed scholars (12.8%) from an overall number of 10.737 persons active in secondary education in 1932/33 (Hartshorne, p. 87ff, 93, 95; Statistisches Jahrbuch für das Deutsche Reich).

Gumbel, in his summary from 1938, refers on page 15 to Hartshornes study as »vorzügliche(s) Buch« containing »wichtige statistische Angaben über die Zahl der Entlassenen«. Instead of referring to »1500 Professoren«, as suggested by Möller, Gumbel states in the first sentence of his introductory essay: »Die Nationalsozialisten haben bis zum Ende des Jahres 1936 ca. 1500 Wissenschaftler abgesetzt.« (3) From the dates and figures cited by Gumbel as well as from the direct quotation it seems evident that he is referring to Hartshorne, according to whom the number of dismissed scientists in staff reduces to 1.510 by leaving aside »recent graduates« and »intellectuals«. The difference in date (April 1936 in Hartshorne as compared to »bis Ende 1936« in Gumbel) is a minor defect attributable probably to sloppy reading.

Möllers errors in his summary are evident:

1. He misquotes Gumbels »ca. 1500 Wissenschaftler« as »1500 Professoren«.
2. He relates this illquoted figure in an entirely misleading way to the number of professors in the year 1930/1, thereby neglecting the fact that categorizations as well as reference dates are different.
3. He concludes from his defect premises that »etwa ein Drittel der haup-

tamtlichen deutschen Hochschullehrer« were dismissed. This conclusion is logically correct but factually false, since the premises of the argument are erroneous.

The second statistical estimation of emigration losses suffered by German science after 1933 which will be briefly examined here is Christian von Ferbers study on »Die Entwicklung des Lehrkörpers der deutschen Universitäten und Hochschulen 1864 - 1954« (4). At face value, the conclusions of this study differ radically from those of Hartshorne. By comparing staff listings from 1931 with those from 1938 von Ferber comes to the conclusion that the total »emigration loss« of Germany in this period amounts to 39% of all academic staff. To accept this figure without qualification is, of course, absurd. This is overseen by many researchers making use of both Hartshorne's and von Ferber's findings in the same argument, not noticing the contradiction. An example of this can be found in Claus-Dieter Krohn's otherwise very valuable study on the New School for Social Research (5). On page 18 he states that in 1933 1.200 scientists and until the end of the thirties another 500 lost their position in Germany, making a total of 1.700 (without Austria and Prag). Half a page later he implicitely declares the first number to represent 16% and the second one third of all teaching staff. This contradiction (if 1.200 were 16%, then 1.700 would at most be 22.7%) is never resolved in Krohn's presentation, although it does in no way affect his subsequent text. It is remarkable that Krohn at the point of his citing the 33%-loss-hypothesis refers to Hartshorne, p. 87ff., because at least in my copy of this book Hartshorne nowhere arrives at this estimation (see above). The deeper reason of Krohn's suddenly jumping at this figure, which he could not have computed from Hartshorne's statistics, thereby corrupting his own argument, becomes clearer two lines later, where the estimation of von Ferber is quoted without further discussion. It seems that what Krohn attempted was to force the two different estimations into line without really erasing the roots of their differing - an unlucky attempt that was to fail in view of the facts. How is the contradiction within Krohn, viz. between Hartshorne and von Ferber to be resolved?

Firstly, it must be noted that von Ferbers study is not dedicated in the first place to a solution of the problem dealt with in this paper. Tables referring to emigration losses are a two-page side product of von Ferber's work. The figures in these tables are computed by simply comparing list of scientists being in service 1931 with lists of scientists being in service 1938. This operationalization imposes serious restrictions on the interpretation of the resulting conclusions, most of which von Ferber himself enlists. The most serious source of error derives from normal fluctuations of academic staff (retirements and deaths), which are by design categorized under

»emigration losses«. That this method could occasionally lead to severe misrepresentations is exemplified in the 79% of »Nichtordinarien« between age 60 and 69 counted as »emigration loss« according to von Ferber's procedure. The author is well aware of the shortcomings of his figures on emigration loss and he would never have claimed them to be authoritative for the ensuing three decades of emigration research. That his resulting figure of 39% should nonetheless acquire among both workers in the field and science administrators the status of a »magic number« was not anticipated by him and cannot be explained by any impeccability in his method of calculating it.

Is there any possibility of separating the loss due to political interference from the total loss? Although direct evidence is scarce in von Ferber, some hints on the true proportions might be derived by analyzing the differential losses of various age cohorts of university staff. In all probability the rate of normal retirements in the group of professors below age 30 will be very low. Losses in this group should therefore be attributed mostly to other factors such as enforced retirements, untimely death, change into industrial-, commercial-, or self-employment, or living on independent means. The numerical relations between the first and the latter possibilities are of course unknown. Another interpretation must be given for the losses in the group of professors over age 60. The figures for this group are an amalgam of normal retirements, forced retirements, illness induced retirements, and deaths in service. Comparing the losses of the two extreme age cohorts (21% for those being 20 to 29 years of age, 34% for those aged 60 to 69), and assuming the rate of dismissals not to be systematically correlated with age, results in an upper limit of forced retirements of »Ordinarien« of 21%. Similar considerations for »Nichtordinarien« leads to the conclusion that the rate of forced retirements should not exceed 30%. The group of the very young staff members without tenure and with a very low salary, working for some post-graduate years in research institutes, should of course experience greater fluctuation than the middle aged group which had in the meantime acquired a more durable position, or felt too old for a change into private economy. After all, job prospects in industry and commerce had considerably improved, as compared to the late Weimar period. In von Ferbers table the difference between the losses of the 20-29 year »Nichtordinarien« cohort (36%) and the 30-39 year cohort (30%) amounts to about 6%. Exempting the medical scientists, where a change into self-employment seemed to be rather normal, the loss of the 30-39 year Nichtordinarien cohort reduces to 28%.

These estimations are corroborated by considerations about retirement rates to be expected under normal circumstances in a sample without a typical age structure. Assuming a mean of 35 years of active service for professors a retirement rate of 20% for the seven year period between 1931

and 1938 should be expected in a normally distributed population. As a consequence of an expanding system of secondary education in the decades preceding the 1930s the proportion of younger staff members should be somewhat enlarged, to the effect that the corresponding retirement rates for the whole population are reduced below normal. To assume a normal retirement rate of approximately 10- 15% for the period between 1931 and 1938 might be not very far off the mark. This would reduce the rate of enforced retirements among von Ferbers categories »Ordinarien« and »Nichtordinarien« from 34.4% to between 19.4% and 24.4%. To blend the exeedingly high (over 50%) »losses« of a third group, especially »Lektoren«, »Honorarprofessoren und Gastdozenten«, and »Lehrbeauftragte und Lehrer« with the first figure to an overall »loss« of 39% seems unsound, as long as no well-founded estimations about normal fluctuations in this group are possible. It should be pointed out that our corrected figures may still be too high, because the effects of other factors besides normal and enforced retirements on losses have not been investigated. We simply lack information about how many of the group died, how many applied for a job outside the university, how many got into a business of their own, how many retired to live on independent means.

How are these conclusions to be evaluated? Firstly, we must emphasize that the qualification of the computed figures as »emigration losses« is misleading. It is well known that many of those forced to retirement or asking for premature retirement did not emigrate - by lack of opportunity or job offer, or by not being in immediate danger - but preferred to live on pension or independent means in Germany. Whether existing results bearing on the proportion of those emigrating to those dismissed or voluntarily retiring (60% according to Gumbel and Wolgast for the University of Heidelberg) can be generalized is as yet unclear (6).

Even the most comprehensive compendium of emigration research currently available will give no definite answer to these questions. Comparing the number of scientists included in the three volumed international Biographical Dictionary of Central European Emigrés 1933-1945« with the number of university staff in Germany before 1933 would again be an instance of relating incommensurable populations. Approximately half of the scientists within the Dictionary emigrated as children or started their academic career in the reception countries. Many of the remaining scientists graduated in Germany but had never been on salary in a German or Austrian academic institution. A lot of chemists, physicists, or engineers had been employed by great industrial companies, in commerce, or in non-university state institutions. On the other hand the Dictionary is not comprehensive. A large group of emigrants cannot be found in it because of either not fulfilling certain criteria of inclusion or lacking information on their life and career.

In view of the present state of emigration research any attempt to reliably and encompassingly estimate the proportion of »brain loss« not attributable to normal fluctuations and the impact of war but to ideological interferences of the Nazi regime with society is bound to fail, if made without further qualifications. In the following I shall argue that any computation of value will only arrive at answers to more restricted questions or run into the hazards of not arriving at any answers at all.

Firstly, the meaning of the term »brain loss by emigration« is ambiguous. How is the concept to be operationalized? The simplest possibility would be to count the pure number of brains lost and set them into proportion to the number of »brains« staying in Germany. The difficulty of the task becomes clear by the fact that even this supposedly crystal clear prescription is beset by serious problems. Its success presupposes that the respective categories of »brains« are neatly separable and identifiable. But given that this problem will be soluble, is this really what we mean by »emigration loss«? It can be reasonably argued that the real loss is not in the proportion of brains but of brain capacity, or scientific competence, leaving the country. Of course, there seems to be no a priori reason why scientific competence should not be normally distributed among the two groups of scientists. But this is, lacking any detailed information, nothing but a further hypothesis. The decisive fact, however, is that as long as this hypothesis remains untested, all inferences from number to quality remain flawed. That this is not an idle, whimsical speculation but a serious problem will become clear in interpreting the data presented below.

Secondly, loss in scientific competence, even if measurable, might not necessarily be a good indicator of cultural loss. Cultural dynamics is nourished by many sources, and the stimuli actually dominating its course are not necessarily deriving from natural science or technology, even though this may be true in most cases. However, there is no reason why the cultural front line«, or the foci of scientific or socio-cultural progress might not occasionally shift to other realms of thought apart from natural science. To avoid any misunderstandings it should be emphasized that any ranking in importance of different scientific disciplines thus established is valid only hie et nunc, in an actually existing, highly specific historical situation. Nevertheless, if emigrants and non-emigrants would turn out not to be normally distributed among »hot« and »dormant«, or focal and non-focal, disciplines, this would be a very important fact in evaluating the quality of the experienced »brain loss«.

Thirdly, what is true for the relations between disciplines, seems to hold as well for the relations between different fields within disciplines. Just as »hot« sciences are to dominate scientific development for some time, only to cool down after a period of exponential growth, certain specialties, or fields, within a science may temporarily provide the main thrust for dis-

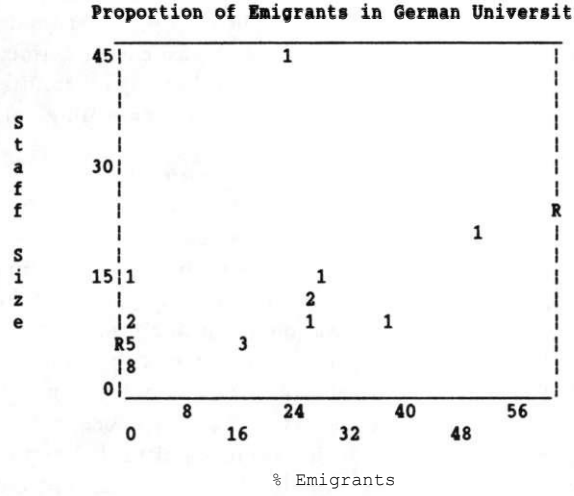
ciplinary development. Like before, this will be unimportant for our problem as long as percentages of emigrants in »hot« and »cold« fields concur. Clearly, no avaraging over different fields within a discipline in calculating »emigration losses« will be admissible in the opposite situation. Any researcher violating this precondition should at least clearly delineate the specific meaning of »emigration loss« actually underlying his results as being »percentage of persons lost through emigration« - a meaning not to be confused with »disciplinary loss«.

To be sure, the task of exactly to determine emigration loss in the former, more straightforward sense is by no means trivial, although prospects to a solution are more encouraging than in the latter case. In the following it will be shown how to tackle with the qualitative problem of disciplinary loss by statistically analyzing hitherto unexplored databases, i.e. the published literature in the field and the information about disciplinary structures and processes implicit in that literature. We shall start with describing a very simple method of establishing quantitative proportions bearing on the problem of disciplinary emigration losses. After that we proceed with diversifying the problem and with introducing more sophisticated methods to its solution - methods that will eventually result in better and more detailed answers to different facets of the problem.

In another paper (7) it was shown that in the case of physics emigrated academicians (exclusive of assistants and members of Kaiser-Wilhelm Institute not giving lectures) represent about 15.5% of the total (50 out of 322). An appropriate database for the statistics was found in calendars for physics published semi-annually by Physikalische Zeitschrift. It was further shown that no less than 40% of these physicists came from only two universities (Göttingen and Berlin), although no more than about 20% of all German physicists were teaching there. Less than half (15) of a total of 36 universities suffered emigration losses, typically the more central ones (with the exception of the very conservative Jena physical institute, which had none). A correlation coefficient between size of teaching staff and percentage of emigrants was computed for universities ($r = .51$) and technical universities ($r=.66$). Regression statistics and plots are given in the figures 1 and 2 (computed with SPSS/PC+).

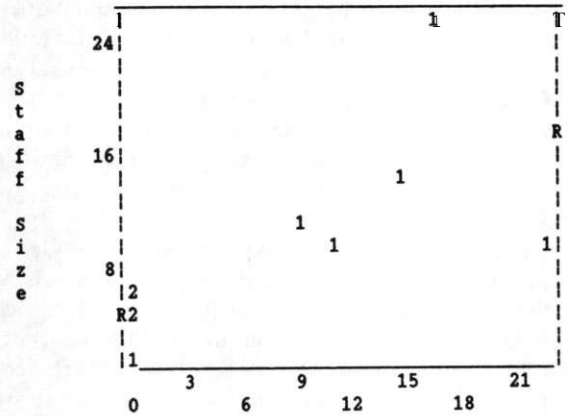
As an analysis of the total emigration loss experienced by the German physics community the data just presented are not satisfactory. It is well known that far more than 50 (or, including Austria and Prag, 61) physicists left the »Third Reich«. Utilizing the information inherent in the »Biographical Dictionary« and in the unpublished list of scholars not included in it the total number of emigrant physicists can be estimated as amounting to between 150 and 200 - depending on disciplinary boundary definitions. The nasty fact, however, is that this figure can no longer be related to the ground sample of all physicists concurrently residing in Germany. No rate of emigration loss can be calculated, lacking information about the whole.

Figure 1: Percentage of emigrants in German Universities of different size (scatterplot and regression statistics)



26 cases plotted. Regression statistics of STAFF SIZE on % EMIGRANTS: Correlation .51331 R Squared .26349 S.E. of Est 7.66806 Sig. .0073 Intercept(S.E.) 5.68337(1.84347) Slope(S.E.) .31231(.10658)

Figure 2: Percentage of emigrants in German Technical Universities of different size (scatterplot and regression statistics)



10 cases plotted. Regression statistics of STAFF SIZE on % EMIGRANTS: Correlation .66350 R Squared .44023 S.E.of Est 5.14357 Sig. .0365 In tercept(S.E.) 5.57256(2.20318) Slope(S.E.) .51413(.20497)

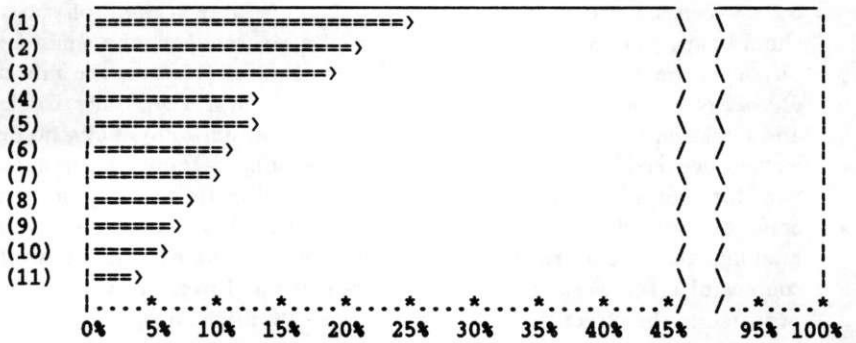
To solve this problem we have to introduce a new procedure. It is valid on the hypothesis of the proportion of German emigrant physicists being about the same as the proportion of the German physics literature written by physicists subsequently emigrating. That is, if emigrant physicists should turn out to have been more prolific writers than non-emigrant physicist, the resulting figure would be no true reflection of the rate of physicists lost by emigration. Relying on a sample of 42.372 physics articles and books enlisted in the German abstracting journal »Physikalische Berichte« between 1925 and 1933 - which represents an equivalent to about two thirds of all physical publications abstracted in the same period - it could be concluded that later emigrants published about 10.8% of the German language literature in the field (2.505 from 23.216). Although possible sources of error were quite numerous, positive and negative biases compensated to the effect that the account seemed well balanced.

Further analysis revealed that the emigrant/non-emigrant publications rate was highly specialty-dependent. The spectrum ranged between the extreme values of 25.1% for quantum theory and 3.8% for acoustics. The statistical results are given in figure 3.

Historical considerations resulted in the conclusion that the proportion of emigrant publications is a good indicator of a specialty's »paradigmatic youth«. An alternative explanation drawing upon a purported correlation between specialty prestige and height of entrance barriers for Jewish scientists could be refuted. This hypothesis asserts that older specialties had greater prestige within the social system of science because of the weight of their institutionalized tradition hitherto established. The crucial fact, however, is that specialty age and time of the specialty's institutionalization do not necessarly concur, and that the proportion of emigrant publications correlates only (negatively) with the former.

In the article adverted to above this was shown in greater detail (8). It was argued that most Jewish physicists experienced themselves, integrational successes notwithstanding, as kind of »socially marginal«. In view of the scarcity of pogroms or other organized antisemitic activity in pre-Nazi Germany this assertion may appear contentious. The crucial events in the construction of a moderately »marginal identity« must, however, not consist in traumatic experiences of violent antisemitism. They can also be implicitly present in an array of tiny, subtle perceptions of non-Jews' slightly modified attitudes and behavior while socially interacting with Jewish people, as compared with their attitudes facing non-Jews. The perception of others' behavior as unnatural or contrived, frequently occuring as a by-product of their unsuccessfully trying to appear »normal« and friedly, can be quite disturbing and irritating for the individual's social identity and self-concept.

Figure 3: Proportion of emigrants in different specialties of physics



(1) Quantum Theory; (2) Atoms and Molecules; (3) Nuclei & Radioactivity; (4) Constitution of Solids and Fluids; (5) Line Spectra; (6) Ideal Bodies/Gravitation/Analytical (Rational) Mechanics; (7) Mechanics of Fluids; (8) Electricity and Magnetism; (9) Mechanics of Solid Bodies; (10) Technical Mechanics; (11) Acoustics.

The decisive fact is that steadily experiencing moderate social marginality, or estrangement, will gradually eventuate in specific cognitive consequences on the side of the individual. Within the social system of science marginality is tantamount to a loosening of social controls enforcing conformity with ruling paradigms and main-stream-views by enacting negative sanctions vis-%a-vis »deviant« overt thought or behavior. Scientists in this position are not likely to invest in elaborating traditional theories, and even less in defending them against new, and apparently falsifying, facts or experiments. Moderately marginal scientists are, on the contrary, more sensitive to the shortcomings of traditional conceptual tools, and for new problems that cannot be solved with their help. For contemporary main-stream-scientists they appear as »sceptics« and »problematizers« rejecting firmly established knowledge, which, to be sure, even in the traditionalists view faces some »minor problems«, for the sake of »wild spe-

culations«. With the advantage of hindsight, however, later historians of science will often judge them to be searchers on the boundary of current knowledge, revolutionizing, if successful, their field of study by just these »wild speculations«. But, tobe sure, the creative benefits of moderate mar ginality are not received free of charge. The individual in this role will experience himself as living in a highly unstable world wherein no certain, or unchanging, knowledge can be achieved. The moderate marginal, being neither »insider« nor »Outsider«, is not a token of Simmel's »Fremder« who lives beyond the »border« in a no man's land. Being no real insider either, he might be metaphorically depicted as acting »on the border of thought« - i.e. in the uncertain, fuzzy region between current and future scientific knowledge. Unrestricted speculation, being a landmark of real scientific outsidership, with its benefits of enabling its defender to create a highly consistent, albeit deviant, counter-world, is not allowed to him. This implies an unceasing cognitive unrestlessness, a never ending, and only biologically terminated, search for better explanations and theories on the basis of the most advanced scientific knowledge which can easily eventuate in cognitive and emotional exhaustion.

It should be stressed that marginality, or estrangement from society thus defined, is not confined to Jewish scientists. Schrödinger is a good case to illustrate this point (9). But what about Heisenberg? Although the janus-faced cognitive consequences of scientific marginality outlined ab-ove seem to apply to him there is no trace of social alienation, or estran-gement, within Heisenberg - at least not in his early years. On the con-trary, just as Plato 2500 years before, Heisenberg seemed to be firmly rooted in his society. This argument, however, ignores the decisive fact that Heisenberg had been scientifically socialized from scratch in an al-ready marginal tradition, i.e. in the quantum theoretical environment of München (Sommerfeld), Göttingen (Born), and Kopenhagen (Bohr). His social situation, therefore, was rather difficult and should have resulted in his experiencing some amount of cognitive inconsistency. Did'nt he rea-lize, after some time of study, the marginality of this scientific milieu? Perhaps, or almost surely, he did realize, and apparently enjoy, it as long as wider political conditions did not interfere with his work. His superior cognitive abilities, in conjunction with his not being beloaded with much tradition (in his »Rigorosum« he failed with Wien in classical physics, and left with »rite« on the intervention of Sommerfeld), and his early success (by the end of 1926 - Heisenberg was just 25 quantum mechanics was acknowledged to have solved the deepest problems of atomic physics - at least in principle - if not in detail), allowed him to play with the ignorant traditionals the delicate game of the youthful revolutionary having achie-ved centrality status among »those who knew« through his intellectual tour de force. The situation got a bit more serious in 1937 after Heisenberg,

along with Sommerfeld and Planck, was offended in the weekly journal of the SS, »Das schwarze Korps«, as »'Weiße Juden' in der Wissenschaft«, and, because of his receiving, and accepting, the Nobel prize in 1933 with Schrödinger and Dirac, as »Der 'Ossietzky' der Physik«. Although Heisenberg again, but now only by serious effort, triumphed over the traditionals, this time personified in the administrators-in-chief of »Deutsche Physik«, Lenard & Stark, and their lot, he was, from then on, never to be the same. The game was over, or rather, it had become deadly serious.

I did not study Heisenberg^ biography carefully enough to be able to really judge the degree of Heisenbergs alienation by this time. But my impression is that these events, along with others, such as the circumstances of the death of his very gifted co- worker Euler - must have caused a deepening rift seperating him from the society he lived in. The subsequent war work, where misunderstood obligation to service his country drew him in, could only be made bearable for his mind by allowing himself extended, and very lonesome (10), journeys into »pure theory«. He worked on meson theory, cosmic ray physics, and in 1943/44 invented S-matrix-theory, which was to become a paradigm for high-energy physics after the war. Concluding the discussion of the caveat to the marginality argument presented above, I dare to hypothesize that Heisenberg is no counterexample.

Statistical results as well as qualitative considerations lend some support to our plead tobe cautious not to confuse different concepts of »emigration loss«. In view of the great loss of »brains« in the central fields of 20th century physics it can be safely argued that the real disciplinary loss of German physics by far exceeded its overall loss as measured in pure number of emigrated physicists. Refined statistical analyses on the basis of citation data presented below will reveal that the disciplinary loss was even greater than indicated above, because the distribution of »scientific excellence« within specialties was biased in favor of (later) emigrants.

Philosophers of science long told us that confirmations are worthless in science, because they can never lend truth to a hypothesis, whereas but one counterexample suffices to prove its falseness. Fieldworkers, on the other hand, have never been very fond of this idea. After all, it is emotionally more gratifying to sample supportive evidence in favor of an already existing, useful, and - to some extent confirmed, hypothesis than toss it over and be left with nothing but a bundle of incompatible, incomprehensible, and unsystematized, data. However, as every fieldworker is likely to have experienced, this research strategy can paralyze the progression of his further work. Confirmations are deceptive, because they can cause the researcher to overestimate the real strength of his pet-hypotheses.

Although not unused to philosophical **arguments** of this sort, the author has to confess to have fallen prey to the sweet **Sedativum** of confirmatory evidence in favor of his hypothesis. In an attempt to check the results of

the literature statistics the membership lists of the »Deutsche physikalische Gesellschaft« were analyzed for their proportion of emigrants. The overall emigration loss of the German physics community computed above on the basis of publication counts as being about 10.8% could thereby be nicely confirmed. 11.25%, or 108 out of 960 natural members residing early in 1933 in Germany, were identified as emigrants. This seemed to settle the issue, because the agreement between the purely literary and the purely person-oriented statistics was really astonishing. It may suffice to only mention that another confirmation was to follow which was provided by measuring the proportion of subsequent emigrant physicists among the authors of three of the leading German physics journals, Zeitschrift für Physik (ZP), Annalen der Physik (AP), and Zeitschrift für Technische Physik (ZtP), before 1933. The resulting figure was 10.7% - in hindsight a not too astonishing result in view of the fact that these journals were but a subsample of the more comprehensive data base of the first analysis.

Gratifying as it was, this result too caused some uneasiness. In view of the high proportion of foreign authors in Zeitschrift für Physik (which had not been eliminated in the procedure) and the quantitative predominance of ZP-articles in the subsample prior considerations had nourished the suspicion that the figure should be a bit lower than that actually calculated. We suspected that, unlike the famous Zeitschrift für Physik, most of the German specialist journals contributing to the literature in the field were far too unknown to most foreign authors to attract their work. This should have resulted in a slightly different (in fact lower) proportion of emigrant physicists in the subsample as compared to the ground sample. That the figure was lower by just 0.09% could, however, be explained by the fact that Zeitschrift für Physik had a much higher proportion of emigrant authors than the rest (14.5% between 1926 and 1933). Apparently this compensated exactly for the greater number of foreign authors. Although not devoid of hidden traps, this result was again very satisfying.

The next step in our analysis was dedicated to construing an »atlas of German physics 1926-1950«. We took advantage of the fact that the three journals named above usually presented its authors with full institutional address, or at least with the name of the home town. This allowed us to construct a data-base from which the geographical and institutional distribution of physicists in Germany for each year between 1926 and 1950 can be deduced - restricted, of course, to those actually publishing in the three journals.

Windfall-profits from this work included the computability of the proportion of foreign authors in the three journals. In the figures 4 and 5 the crosstabulations of the rates of emigrant authors within the different journals are presented. The first table shows the proportion of emigrants among the different German and Austrian authors, the second the pro-

portion of emigrants among all different authors taken together. Every author counts but one time in each journal, so that the same author can count in the same table more than once, but no more than thrice.

These results were staggering. By counting not the proportion of emigrant-authored articles to all articles published in the three journals between 1926 and 1933 but the proportion of different emigrant authors to all different authors the »emigration loss« reduced from 10.7% to 6.2% (Fig. 5). Eliminating all authors not residing in Germany or Austria brought the rate up to 8.9% (Fig. 4), a figure which, however, can no longer be compared to the original, although it indicates that eliminating foreign authors from the original sample, and assuming the foreign proportion to reach an average level of 15%-20% for the total German language physics literature in this period, would raise the emigrant proportion from 10.7 to about 12.7%-13.5%

It should be emphasized that the new results did not invalidate the conclusions of the former paper because we had been cautious to propose the resulting figure to denote »the quantitative contribution of German speaking physicists emigrating after 1933 to the German language physical literature«. After all, this remains perfectly true. The rationale for our decision to use this variety of the different meanings of »emigration loss« is explained more fully in the paper. Suffice it to say here that it was endorsed by the fact that physical science in the time investigated could no longer be treated as an exclusively national enterprise. This was true for the German as well as the English language based physical research. The two main gravitational centers of physical research in the 20th century up to 1933 were attracting many scholars outside Central Europe or GB/USA, respectively. There was a great amount of mobility among scholars toward these centers, to the effect that some of those later emigrating from Germany and being counted as »German speaking emigrant physicists« had really come some time ago from abroad - from Hungary, Poland, Czechoslovakia, the USSR, Switzerland, or Scandinavia. To calculate the truly native German emigration loss would have been a very difficult, and perhaps insoluble, task. Therefore we are rather confident that the figures presented in the other essay will stand future attempts to measure emigration loss as defined in the paper.

The results presented in figures 4 and 5 are highly surprising if compared with the total proportions given above. A comparison reveals that subsequent emigrants published 10.7% of the articles in the three journals, although this group comprised only 6.2% of the different authors of these journals. This can only be explained by assuming that these authors had been much more prolific and productive than the rest. As can be seen from our critique of current emigration research, it is most important to chose the correct reference group in comparing productivity rates. If emigrant

Figure 4: Proportion of emigrant (T) and non-emigrant (F) physicists among all authors of Annalen der Physik (AP), Zeitschrift für Physik (ZP), and Zeitschrift für technische Physik (ZtP) residing in Germany or Austria between 1926 and 1933. Every author appears only once in each column, or journal.

ZS->	Count / Exp Val / Col Pct	AP	ZP	ZTP	Row Total
EM		432	951	349	1732
	F	414.6	981.3	336.2	91.1%
		94.9%	88.3%	94.6%	
		23	126	20	169
	T	40.4	95.7	32.8	8.9%
		5.1%	11.7%	5.4%	
	Column Total	455	1077	369	1901
		23.9%	56.7%	19.4%	100.0%

Figure 5: Proportion of emigrant (T) and non-emigrant (F) physicists among all authors of Annalen der Physik (AP), Zeitschrift für Physik (ZP), and Zeitschrift für technische Physik (ZtP) between 1926 and 1933. Every author appears only once in each column, or journal.

ZS->	Count / Exp Val / Col Pct	AP	ZP	ZTP	Row Total
EM		549	1736	390	2675
	F	539.1	1751.5	384.4	93.8%
		95.5%	92.9%	95.1%	
		26	132	20	178
	T	35.9	116.5	25.6	6.2%
		4.5%	7.1%	4.9%	
	Column Total	575	1868	410	2853
		20.2%	65.5%	14.4%	100.0%

physicists are statistically vastly overrepresented in innovative fields of research (see above), and if it can be further hypothesized that researchers in innovative fields are more prolific writers than researchers in traditional fields, it can be deduced that a difference such as the above one must necessarily occur. A test of the two alternative explanations, viz. (1) the cause of higher publication rates is to be located only in the asymmetrical distribution of emigrants on innovative and traditional physical specialties, and (2) in addition to the difference accounted for by the asymmetrical distribution just mentioned, moderate marginality like that experienced by Jewish physicists in Germany results in a higher achievement motivation which in turn influences the pattern of publishing, can only be provided by within-specialty comparisons. Hypothesis (2) would imply that emigrants in highly innovative fields of research were more productive than non-emigrants in the same fields.

A quantitative analysis of a core specialty of 20th century physics led to the conclusion that the second hypothesis is correct. Emigrant nuclear physicists were more productive than non-emigrant nuclear physicists. This is even true for the time following emigration, especially for German-Jewish immigrants in England and the United States. These are the results of a longitudinal citation study of nuclear physics between 1920 and 1947, comprising approximately 1200 source papers with 14.813 citations. Some results of this study are reported in another paper (11). The figures we are interested in at this point are given below:

Figure 6: Productivity and visibility of emigrant physicists in nuclear physics

Period	1920-25	1926-30	1935	1941	1946/47
a) % Em./all cited authors	5,5	6,7	5,7	4,4	4,2
b) % Em./all cited works	9,2	11,4	7,1	6,5	8,1
c) % Em./all citations	10,4	12,3	8,1	7,6	9,0
index of visibility (b/a)	1,67	1,70	1,25	1,48	1,93
index of acceptance (c/b)	1,13	1,08	1,14	1,17	1,11

Looking, for instance, at the figures of the 1941 period it can be stated that 4.4% of all nuclear physics authors cited in this sub-sample (1147, in absolute numbers) had been emigrants. The same group, however, represented about 6.5% of all authors or coauthors of all different papers (1861, absolutely) cited in 1941. There is a minor possibility that might corrupt our test. If emigrant papers had a much higher chance of being cited than non-emigrant papers a difference of the same kind as shown above should be likely to occur. But there is neither empirical evidence nor any a priori

reason that such a bias did, or should, in fact occur. Lacking an alternative explanation of our results we may conclude that in the years preceding 1941 the avarage emigrant nuclear physicist published approximately 50% more than the avarage non-emigrant nuclear physicist. In the period preceding 1935 the difference was smaller, in the other three periods it was even greater.

This, however, does not exhaust the information content of the table. The systematic differences in the figures of the three rows represent a very strong argument in favor of the thesis that the »real« disciplinary loss experienced by the German nuclear physics community by the emigration of many of its members was

1. higher than indicated by the number of nuclear physicists lost (difference between the first and the second row);
2. higher than indicated by the proportion of the German language nuclear physics literature written by later emigrants (difference between the second and the third row).

We have to admit a possible caveat. It might be argued that summary statistics of the kind presented above are not a good measure of disciplinary influence enacted by certain groups, emigrants and non-emigrants, for instance, if the distribution of citations within the groups is different. Sociological studies of stratification phenomena within the social system of science indicate that one scholar reaching high citation scores might be more influential than many scholars whose added citation scores reach about the same level. That is, scientific influence is not a linear, but an exponential function of scientific excellence, as measured by citation rates. Social stratification in science involves the crystallization of acquired expert functions and temporary leadership roles into meta-stable, self--reproducing, and self-reenforcing, social structures. If this is the case, the disciplinary influence of a sub-group within the field would raise with the concentration of the group's citation rate on fewer scholars, i.e. with its proportion between »chiefs« and »indians«. The influence of the group as a whole will be higher than indicated by the proportion of citations reveived by all group members if the group's index of concentration surpasses the average level, and vice versa. As can be shown by figure 7 below, there can be no doubt that this level of concentration, at least within the group of emigrant nuclear physicist, was far above average.

It should be noted that these figures do not refer to the German but to the total nuclear physics literatur. Nevertheles, the results in column 5 are impressive enough. German nuclear physicists subsequently emigrating represent about 20% of the worlds nuclear physics leadership between 1926 and 1930. Eliminating foreign authors would at least double the proportion for nuclear physics within Germany. The following list of the 26

Figure 7: Levels of citation of emigrant and non-emigrant nuclear physicists 1926-1930.

K-> / EM	Count / Exp Val / Col Per	1	2	3	4	5	Row Total
F		582	191	114	98	39	1024
		561.3	190.8	120.1	105.2	46.5	93.1%
		96.5%	93.2%	88.4%	86.7%	78.0%	
T		21	14	15	15	11	76
		41.7	14.2	8.9	7.8	3.5	6.9%
		3.5%	6.8%	11.6%	13.3%	22.0%	
Column Total		603	205	129	113	50	1100
		54.8%	18.6%	11.6%	10.3%	4.5%	100.0%

(Category K: 1 = 1 citation; 2 = 2-3 citations; 3 = 3-4 citations; 4 = 510 citations; 5 = more than 10 citations in the period.)

most-cited German nuclear physicists (the proper historical category is constitution of atoms and molecules«) should suffice to illustrate this point:

Pos. Ger.	1926-30 All	Name	Emigr.	Citations 1926-1930	1920-1947
1	3	Bothe	N	35	79
2	4	Born	Y	31	53
3	5	Hund	N	27	30
4	6	Heisenberg	N	26	66
5	9	Sommerfeld	N	24	36
6	11	Geiger	N	24	46
7	12	Heitler	Y	23	73
8	13	Franck	Y	23	39
9	17	London	Y	18	21
10	20	Pauli	Migrant	17	36
11	24	Grimm	N	17	26
12	26	Schüler	N	16	49
13	28	Meitner	Y	15	52
14	31	Kudar	Y	14	14

15	32	Schrödinger	Y	14	16
16	33	Biltz	Y	14	17
17	34	Fajans	Y	14	47
18	36	Bonhoeffer	N	14	14
19	40	Debye	Y	13	23
20	42	Stern	Y	12	16
21	43	Meggers	N	12	22
22	44	Eucken	N	12	12
23	45	Sänger	N	11	11
24	46	Wigner	Migrant	11	65
25	47	Ladenburg	Migrant	11	27
26	48	Hahn	N	11	50

Among the 50 physicists processed in category 5 of figure 7 which are enlisted above there were 26 Germans. From these physicists 3 migrated before 1933, 11 emigrated after 1933. Leaving aside the migrants we are left with 23 top atomic and molecular physicists (apart from quantum theory), from which about 50% emigrated! The consequences for nuclear physics in Germany were disastrous. Among the 50 most cited nuclear physicists of the next period (1935) there are but 11 Germans, from which 6 were now living abroad (Bethe, Goldhaber, Meitner, v. Hevesy, Wigner, Szilard, in the order of citation counts). Left in Germany are Schüler (rank 19), Kirchner (rank 36), Bothe (rank 37), Heisenberg (rank 40), and Pose (rank 48). German physics was to become provincial in a field which had grown into the core of physical science between 1930 and 1950. Apart from being short of singular talent or effort, the »critical mass«, or density, of original physical thought needed to achieve high-level performance in nuclear physics was never to be reached again in both Nazi- and post Nazi-Germany. This can be taken as a hint that more indirect »emigration losses« due to former synergetic effects now lacking, and thus far eluding quantitative measurement, have to be accounted for. At this place, however, we can only point out but not solve this problem.

Conclusion

Summing up the preceding discussion we are left with at least three basically different possibilities of operationalizing »emigration loss«. In addition there are several varieties for each of the basic typs:

A. Person oriented definitions

1. The proportion of academic physicists emigrating after 1933. According to this operationalization the emigration loss would amount to about 15.5%.

2. The proportion of all publishing physicists residing in Germany which emigrated after 1933. Applying this definition will reduce the emigration loss to 8.9% (155 emigrant physicists from a total of 1747 physicists residing in Germany or Austria).

B. Literature based definitions

1. The proportion of the German language physics literature written by German speaking physicists subsequently emigrating. According to this definition the emigration loss would amount to 10.7%.
2. The proportion of the literature in the discipline's core fields, i.e. fields providing the main thrust for its development, written by emigrant physicists. Application of this definition would at least double the emigration loss to about 22.6% (atoms and molecules) or 25.1% (quantum theory) for the time before 1931 (the year Physikalische Berichte introduced »nuclei« in its classificatory scheme as a main category).

C. Definitions based on scientific excellence

1. The proportion of all (native as well as foreign) citations of emigrant's publications for physical science as a whole in the period of interest. Lacking appropriate resources this proportion could not be calculated.
2. Same as C.I., but restricted to the current core specialty of physical science. Assuming nuclear physics to represent the disciplinary core in the forth and fifth decades of this century, the proportion of emigrant citations was calculated as amounting to 9.2% for the whole period between 1920 and 1947. Note that this figure cannot be compared with the prededing ones, since the nuclear physics literatures of the other countries are included, and the periods are different. Eliminating the references to foreign publications from the citation data-base as well as all citations to papers published after 1933 would push the »loss of scientific excellence through emigration« up to approximately 25-30%, although the latter figure is an estimation, not a calculation. The estimation is based on the fact that according to Physikalische Berichte 42% of the literature in the field was of German language, and that the proportion of citations to emigrant publications in the whole field of atomic physics between 1920 and 1930 was about 11.5%
3. The proportion of »opinion leaders«, or »chiefs«, or most cited physicists emigrating after 1933. For the core specialty of nuclear physics in Germany this »loss in scientific leadership« was estimated as reaching almost 50%.

Notes

(1) Edward Y. Hartshorne, The German Universities and National Socialism, London 1937.

(2) Horst Möller, Wissenschaft in der Emigration - Quantitative und geographische Aspekte, in: Berichte zur Wissenschaftsgeschichte 7, 1984, p. 2.

(3) Emil Gumbel, Einleitung: Die Gleichschaltung der deutschen Hochschulen, in: ders. (ed.), Freie Wissenschaft. Ein Sammelbuch aus der deutschen Emigration, o. O. (Sebastian Brant/Verlag) 1938, p. 9.

(4) Christian vom Ferber, Die Entwicklung des Lehrkörpers der deutschen Universitäten und Hochschulen 1864-1954, Göttingen 1956.

(5) Claus-Dieter Krohn, Wissenschaft im Exil. Deutsche Sozial- und Wirtschaftswissenschafter in den USA und die New School for Social Research, Frankfurt/New York 1987, p. 18f.

(6) Gumbel, op.cit.; Eike Wolgast, Die Universität Heidelberg 1386-1986, Berlin etc. 1986, p. 144ff.

(7) Klaus Fischer, Der quantitative Beitrag der nach 1933 emigrierten Naturwissenschaftler zur deutschsprachigen physikalischen Forschung, in: Berichte zur Wissenschaftsgeschichte (in print).

(8) Fischer, op. cit.

(9) See P. K. Hoch, E. J. Yoxen, Schrödinger at Oxford: A Hypothetical National Cultural Synthesis which Failed, in: Annals of Science 44, 1987, p. 593-616.

(10) See M. Dresden, H. A. Kramers. Between Tradition and Revolution, Berlin etc. 1987, p. 453ff., on Heisenberg^ rejected attempt to cooperate with Kramers in Leiden on the development of S-matrix-theory.

(11) Klaus Fischer, Die Emigration deutschsprachiger Kernphysiker nach 1933 - Eine kollcktivbiographische Analyse ihrer Wirkung auf der Basis szientometrischer Daten, in: Exilforschung. Ein internationales Jahrbuch, Vol. 7, München 1989 (in print).